



Using system dynamics to develop education for sustainable development in higher education with the emphasis on the sustainability competencies of students



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ABSTRACT

In response to growing concerns of the community about sustainability challenges and the intensification of the international calls to move towards a sustainable future, higher education should be involved in implementing the programs of education for sustainable development; because of this fact that University graduates are part of this solution as future leaders and inheritors of technology. In this study, the underlying research question is: What mechanisms are needed to develop education for sustainable development in higher education with the emphasis on the sustainability competencies of students? The research method was system dynamics. Therefore, we used a mix method research design. Tools of research included the literature review, questionnaire, interview, and observation. We developed a dynamic model to develop the education for sustainable development in higher education with the emphasis on the sustainability competencies of students. This model describes the research problem and predicts the behavior of model variables by simulating in the next 20 years. This model included 18 reinforcing and six balancing feedback loops. After ensuring the validity of the model, mechanisms were elicited from the model. Finally, we evaluated these mechanisms for finding the impacts on improving the problem.

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1. Introduction

A brief look at the status of the world in the recent decades reflects the challenges of sustainability. We know that sustainability index in human activities is not suitable; therefore, if the activities are increased with the unsustainable methods, sustainability challenges would be multiplied. On the other hand, sustainability issue is complex because of the overlap among economic, environmental, and social aspects. Then, there is a need to propose comprehensive and holistic solutions to sustainability challenges. Then, there is a need to propose comprehensive and holistic solutions to sustainability challenges.

In response to growing concerns in society about sustainability challenges as well as the intensification of the international calls to move towards a sustainable future, such as the declaration of decade of education for sustainable development by UNESCO, all educational sectors of society should implement the programs of education for sustainable development (ESD) or sustainability education (SE)

(UNESCO, 2009). Education for sustainable development and sustainability education have the same concept in this article.

The efforts to rethink and revise educational programs towards sustainability which are important for the present and future communities, are the target of education for sustainable development. This educational approach can occur from preschool to university to integrate the principles, knowledge, skills, perspectives, and values associated with sustainability. Accordingly, the role of higher education in social transformation towards sustainable development was determined as a scientific subject and the higher education institutions around the world started to change their educational mission and procedures for integrating sustainability into the educational system (Stephens and Graham, 2010; Holmberg et al., 2008).

Higher education has always responded to the social needs. The goals of the university directly affect the dynamics of technology and social systems (Bursztyn, 2008; Vorley, 2008). Universities can play a critical role in the process of social change that relies on educating new generations of leaders and citizens. Academic freedom of higher education is unique. It has a variety of skills for developing new ideas and meeting the challenges of society (Meadows, 1997).

In fact, higher education fosters many future managers, decision makers, planners, and educators (Bekessy et al., 2003; Fien, 2002). It has the potential to prepare students and increase information and knowledge in order to move towards a sustainable future.

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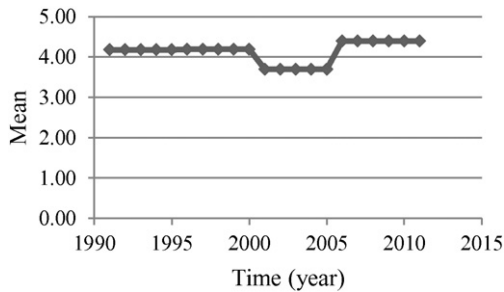


Chart 1. Mean and behavior pattern of sustainability competencies of graduates from 1991 to 2011.

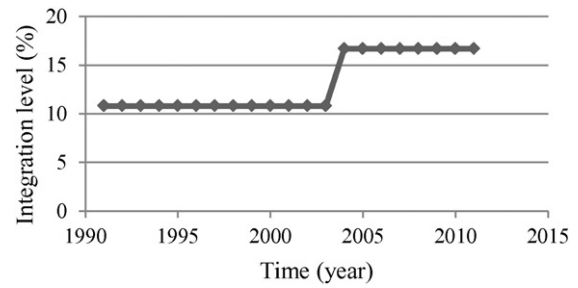


Chart 3. Mean and behavior pattern of integrating sustainability content into curricula of the agriculture and natural resources disciplines from 1991 to 2011.

University graduates as future leaders and inheritors of technology can be part of the solution of sustainability challenges (Woodruff, 2006). Correlations among humans, environment, technology, and politics for a sustainable future are interdependent issues in the community (Cortese, 2003). These issues pass the boundaries of all disciplines. All disciplines need to participate in preparing the community for a sustainable future.

Professionals should be prepared to confront challenges (Mihelcic et al., 2007). They should establish safety, health, and welfare of the community in the best way and attempt to agree with the principles of sustainable development in both the professional and personal life (Woodruff, 2006). This issue occurs under the umbrella of education for sustainable development in higher education. Education for sustainable development affects all components of higher education, such as policy, curriculum, teaching and learning strategies, competencies, assessment, finance, and extra-curricular activities.

Some studies have pointed out the necessity of integrating the programs of education for sustainable development into the higher education (e.g. Figueiro and Raufflet, 2015; Verhulst and Lambrechts, 2015; Lambrechts et al., 2013; Lozano et al., 2013; Barth and Rieckmann, 2012; Brundiers et al., 2010; Chhokar, 2010; Sibble, 2009; Barth et al., 2007; Velazquez et al., 2005; Bryce et al., 2004). The studies showed that higher education should lead to create the knowledge and skills for dealing with global issues such as food security, climate change, water management, non-renewable energy management, biodiversity, health, and social inequality.

The higher education of agriculture and natural resources include these issues. Due to this fact that the inputs in agriculture and natural resources are non-renewable ones, integrating education for sustainable development into this educational system is necessary. Applying unsustainable technologies and policies in managing these resources limits the accessibility of the present and future generation to consumption. According to this, higher education in agriculture and natural resources can train managers, professionals,

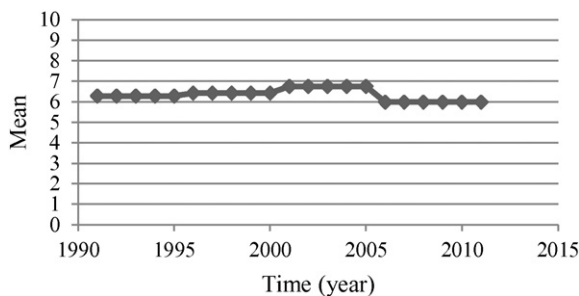


Chart 2. Mean and behavior pattern of science members' competencies for education for sustainable development from 1991 to 2011.

researchers and future leaders who have a mental model based on the sustainability principles, and capability in their practical actions.

Iran's rank in the 2012 Environmental Performance Index report was 118 (Emerson et al., 2012). In Iran, like other countries, the integration of sustainability into higher education was understood, but not seriously and profoundly.

Today's managers are past students; therefore, the mental model of these actors has not formed based on the sustainability principles. In fact, this issue is especially tangible in a way that the progress of the sustainability challenges in the fields of agriculture and natural resources in Iran could be the consequence of paying less attention to the higher education system for integrating education for sustainable development and reinforcing sustainability competencies of students.

We implemented this research in order to show this problem and present solutions to integrate education for sustainable development into higher education with the emphasis on the sustainability competencies in Iran. We selected University College of Agriculture & Natural Resources, University of Tehran, as a case for studying. This case has been implementing a few programs of education for sustainable development, but not with a specific approach.

It is necessary to explain sustainability competencies which provide a framework for developing knowledge and skill of today's students, who are future problem solvers (Willard et al., 2010; Wiek et al., 2011). Sustainability competencies are a combination of knowledge, skills, and attitudes that enable to solve real-world sustainability challenges (Rieckmann, 2012; Wiek et al., 2011; Barth et al., 2007).

Taxonomy of sustainability competencies was presented in the studies such as Wiek et al. (2011), Brundiers et al. (2010), Segalas (2009), Sipos et al. (2008), De Haan (2006), Sterling and Thomas (2006). Based on the literature and viewpoints of subjective experts, sustainability competencies included three classes in this article:

- a. Understanding of the sustainability;
- b. Skills: critical thinking in the sustainability, creative thinking in the sustainability, systemic thinking, empathy, and interdisciplinary collaboration;

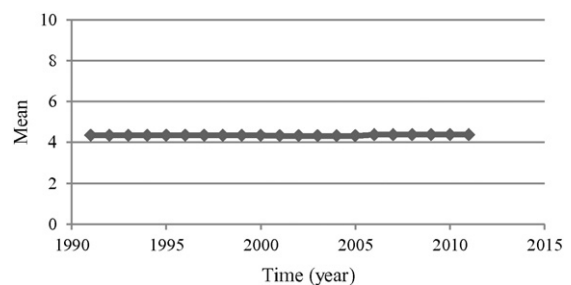


Chart 4. Mean and behavior pattern of applying appropriate teaching and learning strategies for education for sustainable development from 1991 to 2011.

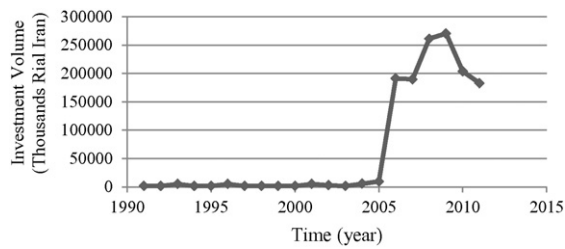


Chart 5. Mean and behavior pattern of investment volume for programs of education for sustainable development from 1991 to 2011.

c. Attitudes: commitment to the sustainability, respect for the past, present and future generations.

Barth and Michelsen (2013) revealed that the emergence of education for sustainable development can change individual action and behavior, and increase inter- and trans-disciplinary collaborations. On the other hand, these collaborations are one of the pillars of education for sustainable development (De la Harpe and Thomas, 2009; Ferrer-Balas et al., 2008; Hogan and Tormey, 2008; Cohen, 2007; Swansborough et al., 2007; Sterling and Thomas, 2006; Dawe et al., 2005; Velazquez et al., 2005; Sterling, 2004).

In order to develop the sustainability competencies in the universities, they should create teaching and learning settings which can be characterized by aspects such as inter- and trans-disciplinary, participation, problem-orientation as well as the linking of formal and informal learning (Barth and Rieckmann, 2012; Rieckmann, 2012;

Wiek et al., 2011; Brundiens et al., 2010; Baartman et al., 2007; Voorhees, 2001; Barth et al., 2007). Moreover, Rieckmann (2012) and Sibble (2009) underlined that the university should integrate education for sustainable development into its curricula in order to enable future professionals to cope with issues of sustainable development in their work.

Some studies point out that sustainability content should be integrated into the curriculum, please refer to James (2009), The Higher Education Academy of the UK (2006), Velazquez et al. (2005), and Ali Baigi (2005). Lipscombe et al. (2008) emphasized on programs of education for sustainable development as extra-curricular activities and the connection of these activities with curriculum and physical actions at the university.

Additionally, some studies (De la Harpe and Thomas, 2009; Cohen, 2007; Litzinger et al., 2007; Fien, 2006; The Higher Education Academy of the UK, 2006; Ali Baigi, 2005; Kolb and Kolb, 2005; Trigwell and Prosser, 2004; Fenner et al., 2004) manifest the role of the pedagogy in reinforcing competencies of students in education for sustainable development.

Shephard (2008) presents that teaching and assessment in higher education mostly focus on cognitive skills of knowledge and understanding rather than on the affective domain (values, attitudes and behaviors) while the attention to affective domain could benefit sustainability education. Moreover, science members' capacity building and professional development for education for sustainable development help the universities to reinforce sustainability competencies of students (Barth and Rieckmann, 2012; Svanstrom et al., 2008; The Higher Education Academy of the UK, 2006; Velazquez et al., 2005; Ferrer-Balas, 2004; Thomas, 2004; Rowe, 2002).

Table 1

Analyzing the behavior pattern of the key variables in the period from 1991 to 2011.

Key variables	Measurement
Sustainability competencies of students/graduates	This variable includes eight competencies consisting understanding of sustainability, critical thinking in the sustainability, creative thinking in the sustainability, systemic thinking, empathy, interdisciplinary collaboration, commitment to the sustainability, and respect for the past, present and future generations. System thinking and understanding of the sustainability were measured through conceptual map analysis. Other competencies were measured through a researcher-made questionnaire with Likert-type items. Items were extracted from the related studies (e.g. Segalas et al., 2009; Holmberg et al., 2008; Alliance for Global Sustainability, 2006; Juarez-Najera et al., 2006; The Higher Education Academy of the UK, 2006; UNESCO, 2005; Tilbury and Cooke, 2001). Please see Appendix A, sections A-G. The Statistical population included Bachelor graduates from 1991 to 2011 at the University College, and 120 of them were selected as a sample.
Science members' competencies for education for sustainable development	Collecting data was conducted through a questionnaire with inspiration from model of curriculum, competences, sustainable development, and teacher training (CSCT) (please see Appendix B). This questionnaire consisted of 54 items (scales of 1 to 10). There are three overall competencies: teaching, reflecting/visioning, and networking. Also, five domains (knowledge, systems thinking, emotions, ethics and values, and action) relate to all overall competencies (Sleurs, 2008). Statistical samples were 40 science members at the University College. They were selected by Cochran's sample size formula and questionnaires were given to them.
Applying appropriate teaching and learning strategies for education for sustainable development	To achieve the behavior pattern of this variable, a questionnaire was designed (please see Appendix A, section H). This questionnaire consisted of 27 items (scale of 1 to 10) which are teaching and learning strategies for education for sustainable development.
Volume of investment for programs of education for sustainable development at the University College	Documentation review and academic events, interviews (with farms and gardens managers at the University College, technical affairs manager, manager of consultation center, and manager of extra-curricular activities, president of science & technology park, president of botanic garden), and observation of the University College environment were used to identify programs of education for sustainable development. These actions at the University College included recycling, green spaces, compost making, limitation of transportation, holding conferences and workshops, applying sustainable technologies in the University College's farms, and holding informal courses such as critical thinking for students. Then, the volume of investment of each action was calculated. In order to analyze investment volume in the period from 1991 to 2011, the formula of Time Value of Money was applied by considering 1991 as the base year and with an inflation rate of 15%.
Percentage of integration of sustainability content into curricula of agriculture and natural resources disciplines	We analyzed the percentage of integration of sustainability content into curricula of agriculture and natural resources disciplines in the period from 1991 to 2011 using the method of the content analysis. In our analysis, the main category was sustainability. Generic categories were environmental, social, economic, and institutional dimensions. Also, 31 of sub-categories were selected based on the studies (Hurlimann, 2009; Kagawa, 2007; Lourdel et al., 2007; Institution of Environmental Sciences, 2006; Dawe et al., 2005). Please see Appendix C. Finally, 191 curricula analyzed manually.

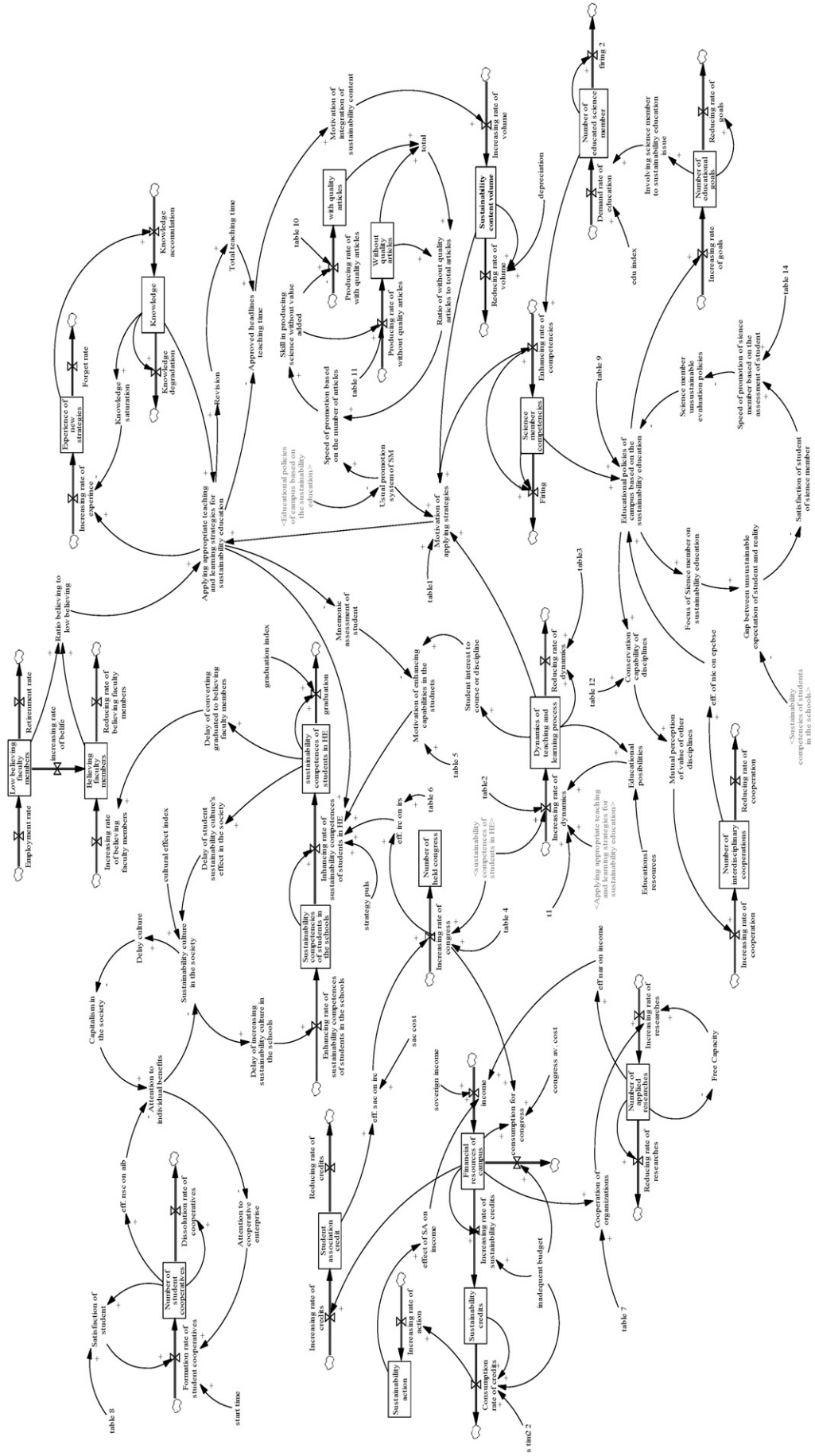


Chart 7. Stock-flow diagrams.

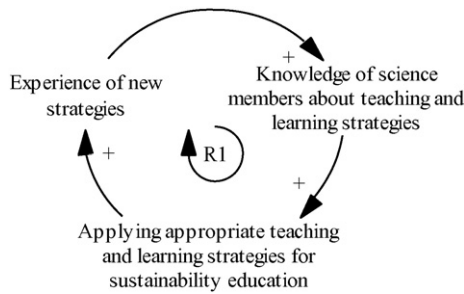


Fig. 1. Reinforcing loop of pedagogical capacity building.

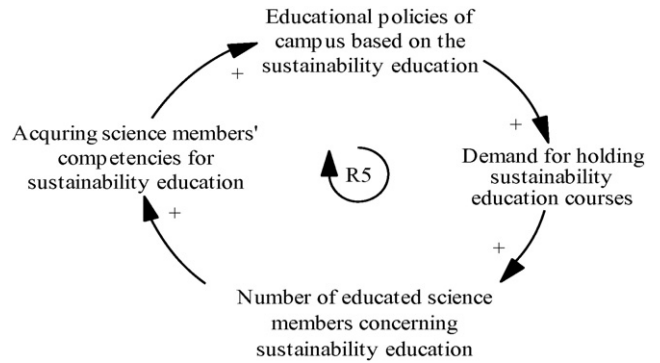


Fig. 5. Reinforcing loop of increasing holding of courses concerning education for sustainable development for science members.

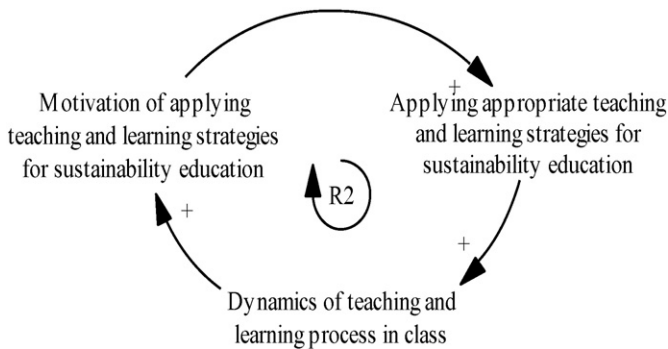


Fig. 2. Reinforcing loop of increasing the motivation of applying appropriate teaching and learning strategies for education for sustainable development.

Integration of education for sustainable development into the higher education needs culture building, financial aids, and research funding (for making networks among university, government, organizations, and society) that in some studies have been suggested (De la Harpe and Thomas, 2009; Ferrer-Balas et al., 2008; Lang et al., 2006). The commitment of the university to sustainability and appropriate educational policies both are necessary for implementing education for sustainable development (Van Dam-Mieras, 2006; The Higher Education Academy of the UK, 2006; Noonan and Thomas, 2004).

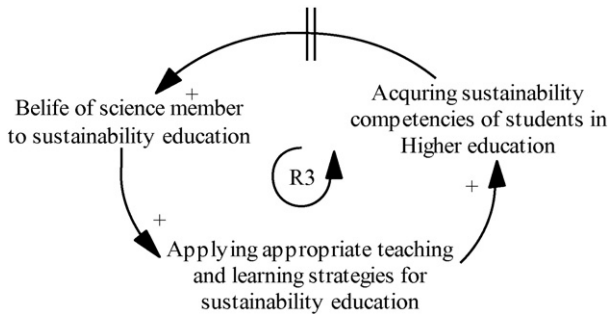


Fig. 3. Reinforcing loop of increasing the belief of the science members to education for sustainable development.

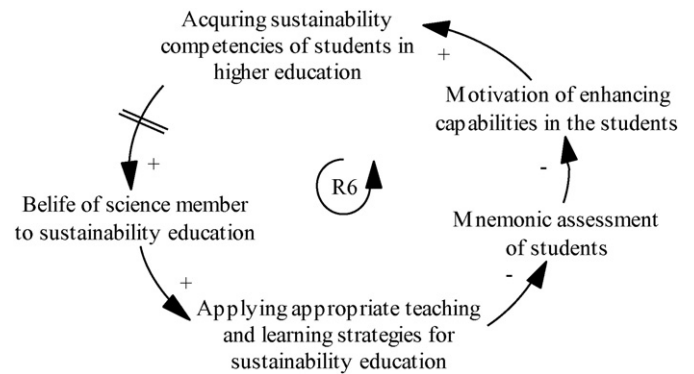


Fig. 6. Reinforcing loop of tendency of students to change.

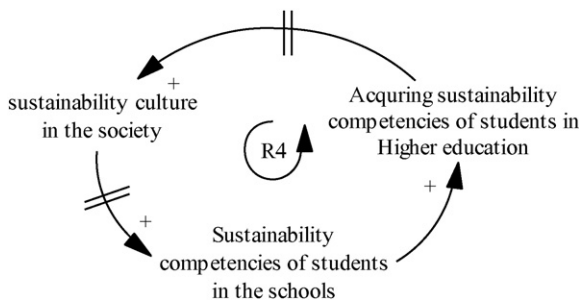


Fig. 4. Reinforcing loop of improving the quality of sustainability competencies of newcomer students.

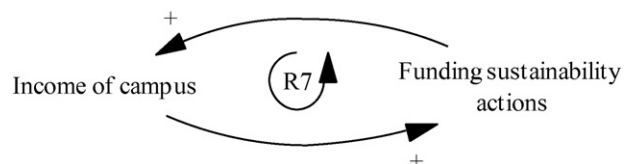


Fig. 7. Reinforcing loop of increasing the funds for the programs of education for sustainable development at the University College.

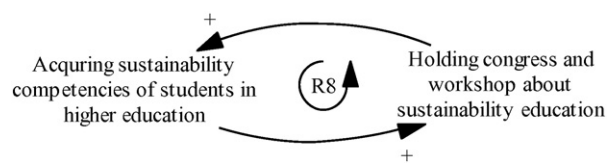


Fig. 8. Reinforcing loop of increasing holding congress, workshops, and lectures on education for sustainable development.

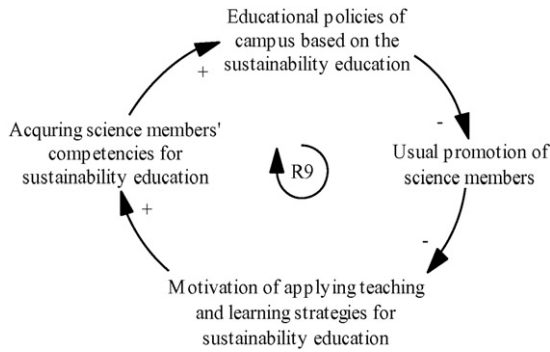


Fig. 9. Reinforcing loop of increasing science members' competencies for education for sustainable development.

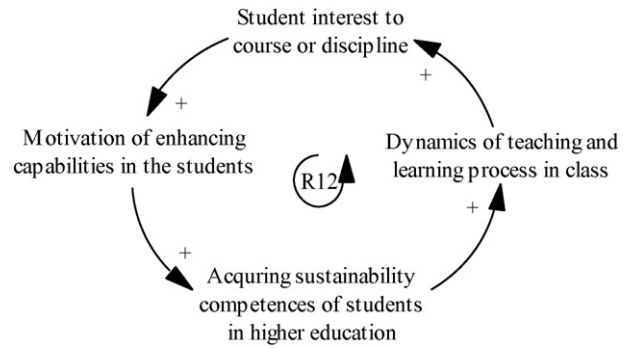


Fig. 12. Reinforcing loop of increasing the motivation of reinforcing sustainability competencies of students.

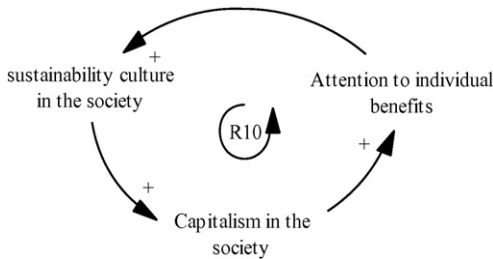


Fig. 10. Reinforcing loop of reducing sustainability culture in the community.

Finally, we mention that underlying question in this article is:

- What mechanisms are needed to develop education for sustainable development in higher education with the emphasis on the sustainability competencies of students?

2. Material and methods

This study was done at University College of Agriculture and Natural Resources, the University of Tehran as a case study. In this study, the system dynamics method was applied. It is a mixed method research design and it starts with the exploration. In accordance with this research method, the problem situation in the University College is modeled. In addition, we did this research from 2010 to 2013.

According to the five-step method of system dynamics (Sterman, 2000), the executive procedures and methods of collection and analysis of the data have been explained step-by-step. All steps have the qualitative-quantitative paradigm. (We presented Appendix D for more understanding of the research process.)

- Step 1: Problem articulation
- The real problem: What mechanisms are needed to develop education for sustainable

development in higher education with the emphasis on the sustainability competencies of students?

- Identifying key variables: These variables provide a reasonable starting point for the conceptualization of the feedback structure governing the dynamics (Sterman, 2000). In fact, promoting the status of the key variables is equal to improving the status of the research problem. Reviewing the literature, clarifying the goal of research, accessibility to data, and viewpoints of experts conducted us to identify the key variables of problem including:
 - Sustainability competencies of students/graduates;
 - Science members' competencies for education for sustainable development;
 - Applying appropriate teaching and learning strategies for education for sustainable development;
 - Volume of investment for programs of education for sustainable development;
 - Percentage of integration of sustainability content into curricula of agriculture and natural resources disciplines.

- Time horizon: How far in the future should we consider? How far back in the past lie the roots of the problem? (Sterman, 2000). In this study, the time horizon is 40 years (1991–2031). The duration that is determined in the future is 20 years and the duration of identifying the problem in the past has been considered 20 years. The start time was 1991; in fact, it was the time that different universities in the world began sustainability education in practice.
- Behavior mode: Modelers seek to characterize the problem dynamically. The behavior mode is considered as the behavior pattern which shows how the problem arose and how it might develop in the future. They are important for understanding the problem and designing policies to solve it (Sterman, 2000). In the first stage, we analyzed behavior mode of key variables in the period from 1991 to 2011. Then, we drew behavior patterns of them based on the mean (average)

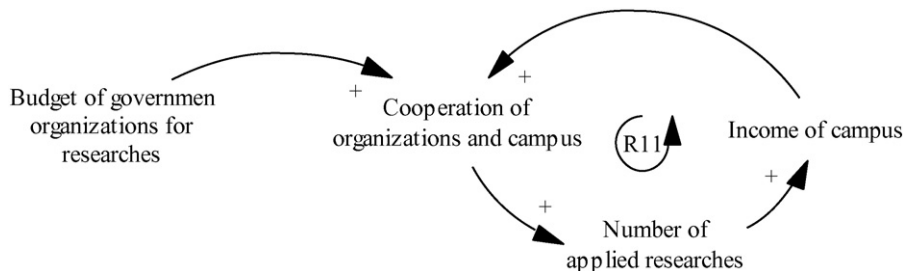


Fig. 11. Reinforcing loop of increasing the applied research.

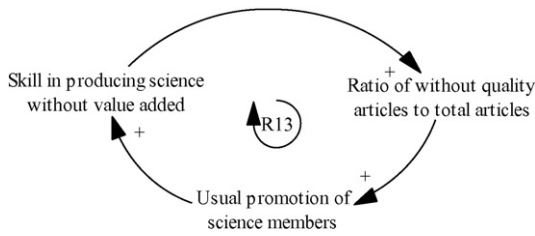


Fig. 13. Reinforcing loop of promoting the science members through the change of research quality.

which had been calculated in the first step (Charts from 1–5). How to measure behavior pattern of the key variables were presented in Table 1. In this stage, the focus is on showing behavioral changes of key variables during these years.

- Step 2: Formulation of a dynamic hypothesis:
 - Identifying initial hypotheses based on a description of the problem: To identify the dynamic hypotheses, literature review, causal layered analysis (CLA) (Inayatullah, 2007), and analysis of behavior patterns of key variables were used. For causal layered analysis, we interviewed with 30 science members and 75 graduates informally and face-to-face. Of course, we did their interviews while they were filling out the questionnaire. Then, we gained and registered narratives and identified initial hypotheses.
 - Developing a dynamic hypothesis: We held two focus group sessions for emphasizing initial hypotheses (with science members and socioeconomic systems experts). Each hypothesis is a causal loop that can be reinforcing (positive) loop (R) or balancing (self-correcting or negative) loop (B) (Sterman, 2000). After the focus groups, casual loops were connected together through their common variables and the dynamic model was developed. The model was developed from the interviews and discovery processes. We have analyzed the research problem from horizontal and vertical dimensions. Horizontally, we identified different players and stakeholders into the problem. We analyzed obvious behaviors, plays, and play structures and rules which existed among the players of the problem, as well as mental models of players through vertical analysis. This analysis explored the latent rules of obvious plays. Then, we have described the relationship between rules and behaviors of players. Because of the complexity of these relationships, we reached a dynamic model that summarized all narratives (Chart 6). This model gave us an insight for proposing the mechanisms to solve research problem in this complex space. The most important feature of this model might be dynamics and having a time horizon. It can examine outcomes and consequences of long-term decisions.
- Step 3: Formulation of a simulation model:
 - Simulation of variables and their relationships need to analyze the system behavior in the time horizon. In this article, Vensim (Ventana Simulation Environment) software was used. Based on the causal loops, stock-flow diagrams were mapped in Vensim software. The researcher should discriminate stock variables from flow variables. A stock variable is measured at one specific time and represents a quantity existing at that point in time which may have accumulated in the past. A flow variable is measured over a time interval. Therefore, a flow would be measured per unit of time. Stocks are represented by rectangles and inflows are represented by a pipe adding to the stock. Outflows are represented by pipes pointing out of the stock. Valves control the flows. Other variables in the

model are auxiliary variable. Chart 7 presents stock, flow, and auxiliary variables.

After drawing stock-flow diagrams, we used methods of interpolation and weight function for formulations of diagrams.

- Step 4: Validation and model testing:
 - Validation is a continuous process of testing and building confidence in the model. At this stage, after the simulation, we tested the model by the method of behavior reproduction. The results of it are presented later.
- Step 5: Policy design and evaluation:
 - Policy design: What might new decision rules, mechanisms, and structures be implemented in the real world? What are the effects of the policies?
 - Interactions of policies: Do the policies interact? Are there synergies?

3. Results and discussion

3.1. Behavior patterns of key variables

The behavior patterns of the key variables have been presented in Charts 1, 2, 3, 4 and 5. In the period from 1991 to 2011, the total mean of sustainability competencies of graduates was 4.12. The means of applying appropriate teaching and learning strategies for education for sustainable development and science members' competencies were respectively 4.32 and 6.36 out of 10. Also, the mean of integration of sustainability content into curricula of agriculture and natural resources disciplines was 13.05%.

In these charts, the vertical axis title is the mean of variables. Diagrams confirm that since 1991, this University College has not followed serious and targeted programs for education for sustainable development. So, these patterns helped us to explore loops which caused such behaviors in the key variables during this period.

3.2. Dynamic hypotheses

Based on the methods presented in the second step of the system dynamics, about 40 initial hypotheses were identified. After validation process, 18 reinforcing loops and six balancing loops were confirmed. Each of hypotheses has a narrative. Based on their narratives, a title for each of them was selected. The hypotheses are as follows.

R₁ loop: Pedagogical capacity building.

This loop (Fig. 1) is related to the pedagogical knowledge of science members concerning education for sustainable development. More pedagogical knowledge increases the applying appropriate teaching and learning strategies for education for sustainable development. Diversity in strategy interacts with the experience of new strategies and experience influences new pedagogical knowledge. Therefore, the loop shows the resultant growth of pedagogical capacity building in science members. This change may be unnoticeable in a period until it reaches a certain threshold level such as saturation of knowledge or experience.

R₂ loop: Increasing the motivation of applying appropriate teaching and learning strategies for education for sustainable development.

The dynamics of teaching and learning process persuade the science members to apply appropriate strategies for education for sustainable development. These strategies create the dynamics of class (Fig. 2).

R₃ loop: Increasing the belief of the science members to education for sustainable development.

This loop (Fig. 3) is related to the relationship between the belief of the science members to education for sustainable development. It increases the application of appropriate teaching strategies for education

for sustainable development that reinforces the sustainability competencies of students. With a long delay about nine years, the believing students to education for sustainable development could be a believing science member in the future.

R₄ loop: Improving the quality of sustainability competencies of newcomer students.

Based on this loop (Fig. 4), the extension of sustainability culture in the community influences sustainability competencies of people such as newcomer students to the university. This impact increases the effectiveness of education for sustainable development at the university. With a delay of 10–15 years, graduates can influence thinking and behavior of urban and rural communities and help to extend sustainability culture in society.

R₅ loop: Increasing holding of courses concerning education for sustainable development for science members.

Science members are developers of the policies of the University College. If they are educated for education for sustainable development, they would develop the related policies. Operating policies need the skills. As a result, the importance of the development of education for sustainable development is identified. Then, the demands of science members for participating in courses will increase (Fig. 5).

R₆ loop: Tendency of students to change.

Currently, the students are evaluated based on cognitive domain which includes especially remembering and understanding levels of this domain. When the affective domain is not considered, students are not motivated to change capabilities as a graduate. Therefore, sustainability competencies aren't reinforced. A student who doesn't believe in sustainability, couldn't apply appropriate teaching strategies for education for sustainable development in the future as a science member. Then he will evaluate his students through remembering level (Fig. 6).

R₇ loop: Increasing the funds for the programs of education for sustainable development at the University College.

Funding the University College for the programs of education for sustainable development has two consequences: firstly, reducing the use of the resources by applying sustainable technologies in farms and gardens; secondly, earning income by selling compost. Revenues from saving or selling could be funded for the sustainability actions (Fig. 7).

R₈ loop: Increasing holding congress, workshops, and lectures on education for sustainable development.

Based on this loop (Fig. 8), holding congress and workshops increase sustainability competencies of students and conversely.

R₉ loop: Increasing science members' competencies for education for sustainable development.

This loop (Fig. 9) explains that science members develop the University College' educational policies; therefore, their competencies for education for sustainable development influence the development of policies. If the policies are tended towards the education for sustainable development, the promotion system of science members is reformed. When teaching and learning strategies for education for sustainable development are used more, science members are persuaded to acquire their competencies for education for sustainable development.

R₁₀ loop: Reducing sustainability culture in the community.

The capitalism considers the individual benefits more than collective benefits. This issue reduces sustainability culture in the society. The extension of this culture reduces capitalism (Fig. 10).

R₁₁ loop: Increasing the applied research.

This loop (Fig. 11) is related to the cooperation of organizations and the University College through research. Networking the University College with different organizations has financial profit through doing research. This profit could be spent on future researches with these organizations. In this loop, a budget which organizations allocate to researches, influences their cooperation with University College.

R₁₂ loop: Increasing the motivation of reinforcing sustainability competencies of students.

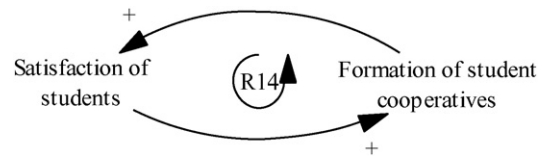


Fig. 14. Reinforcing loop of increasing the demands of the student cooperatives.

Students are interested in their discipline by dynamics of teaching and learning processes in class. Therefore, they are motivated for reinforcing the sustainability competencies which increase the dynamics of class (Fig. 12).

R₁₃ loop: Promoting the science members through the change of research quality.

Right now, the cycle of promotion system is repeated based on the number of publications and without attention to the added value of science (Fig. 13).

R₁₄ loop: Increasing the demands of the student cooperatives.

Farms of University College are assigned through Science and Technology Park to students in the format of student cooperatives. Students implement their knowledge into practice. Therefore, they have a sense of satisfaction. This satisfaction influences the tendency of other students to establish cooperative (Fig. 14).

R₁₅ loop: Changing the students' viewpoints concerning attention to individual benefits.

The formation of the student cooperatives reduces attention to individual benefits and increases the social perception of students. Therefore, they are attracted to the collective activities and demands of formation of cooperatives are increased among students (Fig. 15).

R₁₆ loop: Increasing the interdisciplinary cooperations among departments.

When educational departments don't have any links inside them, it is impossible to have interdisciplinary cooperations. The University College' policies concerning education for sustainable development increase the mutual perception of disciplines from each other that leads to the interdisciplinary cooperation. This type of cooperation is one of the goals of education for sustainable development (Fig. 16).

R₁₇ loop: Increasing the revision of curriculum.

According to this loop (Fig. 17), revision of curriculum and removing irrelevant content increase the space and time for integrating sustainability content. Then sustainability content is more likely to be integrated into the curriculum. Teaching sustainability content needs the appropriate teaching and learning strategies for education for sustainable development. Applying these strategies interacts with the revision of curriculum.

R₁₈ loop: Increasing the interaction between higher education and school.

The increase of the sustainability culture in school causes the reinforcement of the sustainability competencies in the community. Therefore, the community put pressure on the higher education for integrating sustainability. This condition reduces inappropriate expectations of newcomer students from education. Consequently, the University College moves towards policies of education for sustainable development.

Thus, all of the higher education components such as learning and teaching strategies, students and science members' competencies, promotion system of science members and curriculum are changed. The impact of this change is the reinforcement of sustainability competencies of students as members of society who can help to extend sustainability culture. Fig. 18 presents this narrative.

B₁ loop: Integrating the sustainability content.

This loop (Fig. 19) explains that sustainability content volume, the time duration and the strategies of teaching influence the integration

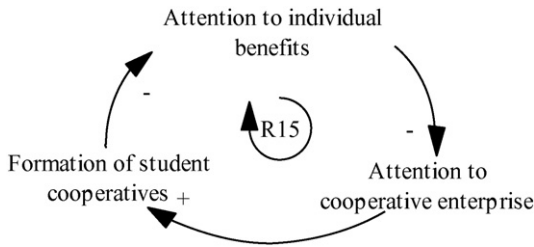


Fig. 15. Reinforcing loop of changing the students' viewpoints concerning attention to individual benefits.

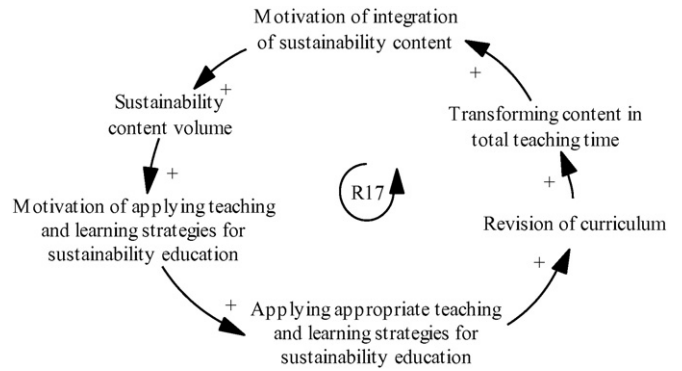


Fig. 17. Reinforcing loop of increasing the revision of curriculum.

of sustainability content into the curriculum. Applying appropriate teaching strategies for education for sustainable development in class takes time that may reduce the motivation of the science members for applying.

B₂ loop: Allocating the credits to students' associations.

Based on this loop (Fig. 20), the part of the University College's income could be allocated to students' associations for holding congress and workshops on sustainability. In this regards, activities of students' associations could not be a source of income for the University College. It leads to financial costs for the University College. This issue restricts the allocation of credits to students' associations.

B₃ loop: Alignment of the policies with the expectations of the students from education.

Students in high school are often educated by conventional teaching methods. Therefore, They expect to use these methods in university. This expectation is illogical and wrong, so we called it 'unsustainable expectation' because it is far from reality. Based on this cycle, the lack of policies of education for sustainable development at the University College interacts with the focus of science members on education for sustainable development. This focus reduces the gap between unsustainable expectation and reality (Fig. 21).

B₄ loop: Resource limitation in implementing the applied researches.

When the number of applied research is increased by the interaction between organizations and the University College, resource limitation is created. It leads to the reduction in the number of applied researches (Fig. 22).

B₅ loop: Acquiring the pedagogical knowledge.

It is possible that science members feel the saturation of knowledge in the process of acquiring pedagogical knowledge for education for sustainable development. It reduces the motivation for acquiring practical experience of new teaching and learning strategies for education for sustainable development; as a result, the process of acquiring knowledge is stopped (Fig. 23).

B₆ loop: Dynamics of the process of teaching and learning in class. This loop (Fig. 24) explains that limitation of educational facilities interacts with the dynamics of the process of teaching and learning.

3.3. Developing a dynamic model

24 dynamic hypotheses were connected together through common variables. The dynamic model was developed. Chart 6 shows the dynamic model to develop education for sustainable development in higher education with the emphasis on the sustainability competencies of students of agriculture and natural resources.

3.4. Formulation of simulation model (drawing stock-flow diagram)

For the more understanding of system behavior in the period from 1991 to 2031, the loops should be formulated and the variables should be simulated by using software. We drew stock-flow diagrams for formulating the model (Chart 7).

3.5. Validation and model testing

The testing model was done through structural and behavioral validation. Structural validation of the model was supported by a formatting model based on the mental models of the science members, graduates, managers, holding focus groups, drawing stock-flow diagrams, and the formulation of the model.

Behavioral validation of the model was supported by the results of the test of the behavior reproduction (Charts 8, 9, 10, 11, and 12). The results have been presented in Charts 8–12. Based on this

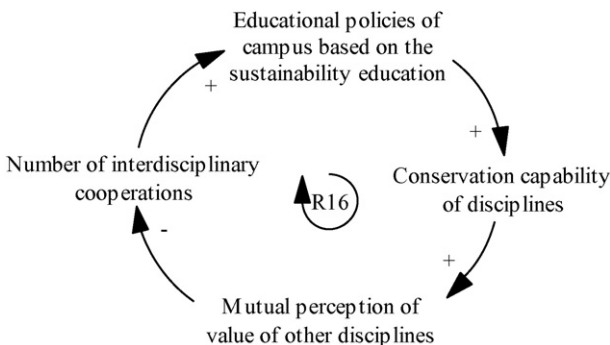


Fig. 16. Reinforcing loop of increasing the interdisciplinary cooperations among departments.

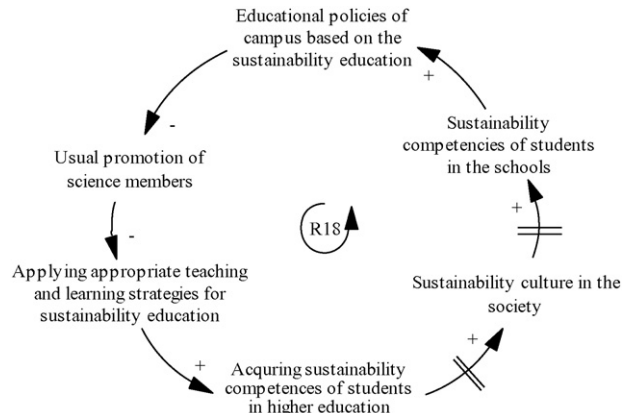


Fig. 18. Reinforcing loop of increasing the interaction between higher education and school.

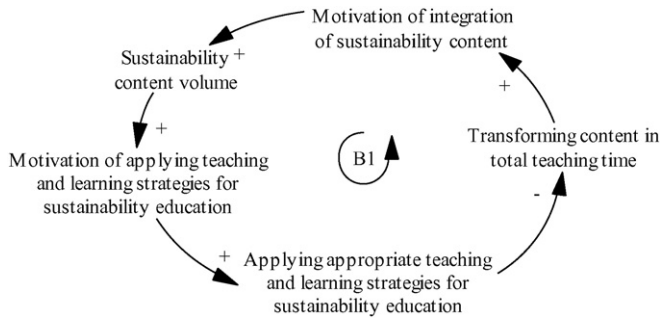


Fig. 19. Balancing loop of integrating the sustainability content.

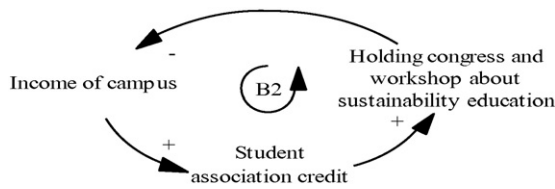


Fig. 20. Balancing loop of allocating the credits to students' associations.

test, the simulated model should reproduce the behavior pattern of the key variables. The results showed that simulation of the behavior of the key variables was in accordance with the behavior pattern of them, which we measured and drew in section 1 of results. Therefore, the model is valid. In these charts, the vertical axis title is the mean of the level of the variables in the period from 1991 to 2011.

3.6. Identifying and evaluating the mechanisms

Each of the hypotheses in the dynamic model indicates the factors and processes that should be considered for solving the problem. Therefore, the model gave us the ideas for identifying the fundamental mechanisms. The mechanisms were evaluated by parametric and structural changes in the dynamic model. For the parametric change, we change the parameters of variables in the model. For the structural change, we add an external variable to the model.

We evaluated the mechanisms and analyzed the effects of each of them. Because of the complexity of the model, interactions of mechanisms were examined and it was clarified that the mechanisms in interaction with each other have better effects on the model and especially on the key variables of the model. Therefore, in this article, we presented results of interactions on key variables of the model.

3.6.1. Evaluating the mechanisms

The first mechanism includes holding a compulsory course to familiarize newcomer students with the basic concepts of sustainability competencies. For evaluating it, we added an external variable to model that directly influences the variable of 'gap between unsustainable expectation of students and reality' in the B₃ loop.

The second mechanism includes holding educational courses for science members on appropriate teaching and learning strategies for education for sustainable development. We evaluated this mechanism through the change in the level of 'education index'.

The third mechanism includes holding meetings of strategic dialogue among different disciplines at the University College. By structural change, we evaluated this mechanism. An external variable of 'holding meeting' was added to model through a relationship with the variable of 'conservation capability of discipline'. We assumed that if meetings are held four times a year, what are their possible effects on key variables of the model.

The fourth mechanism includes the cooperation of government for promoting sustainability culture. This mechanism in practice includes two sub-mechanisms. In sub-mechanism (4-1), starter of the mechanism is the government and in sub-mechanism (4-2), the starter is the University College. Sub-mechanism (4-1) should be implemented earlier than sub-mechanism (4-2). We examined this mechanism through increasing 'cultural effect index' in the model.

The fifth Mechanism includes developing student cooperatives. For evaluating this mechanism, 'facilitation in the cooperative development index' was added to the model through an effect on the variable of 'formation rate of student cooperatives'. Facilitators can be financial or legal aids.

The sixth mechanism includes developing the cooperation between the University College and governmental or private organizations. We increased the level of 'cooperation with organizations' to 25% of current situation due to evaluating this mechanism.

The seventh mechanism includes revising curricula of specialized courses of disciplines. In this mechanism, we examined the 20% change in the curricula of specialized courses for integrating sustainability content into curricula.

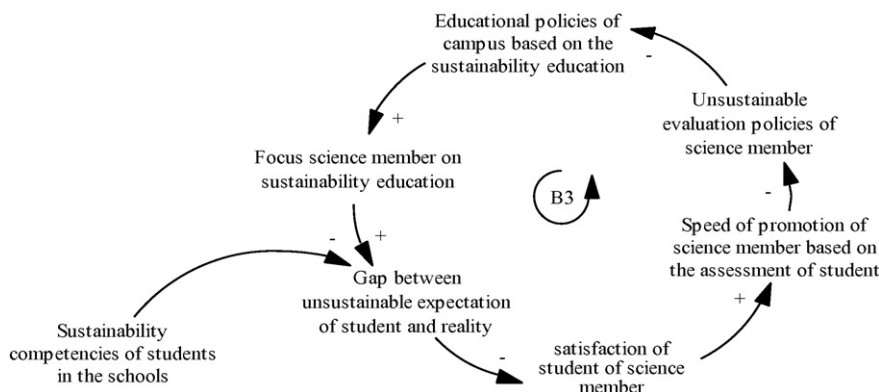


Fig. 21. Balancing loop of alignment of the policies with the expectations of the students from education.

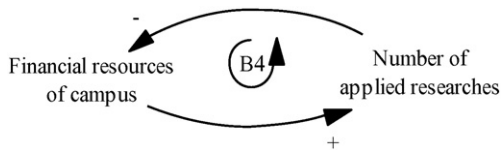


Fig. 22. Balancing loop of resource limitation in implementing the applied researches.

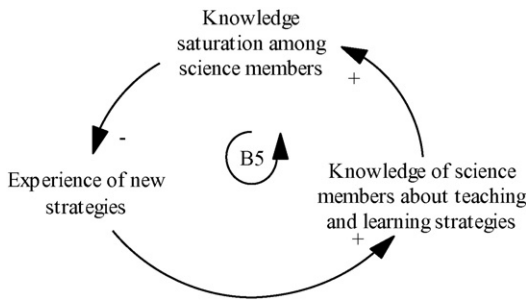


Fig. 23. Balancing loop of acquiring the pedagogical knowledge.

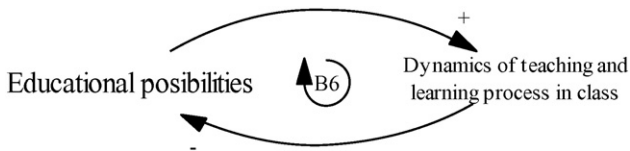


Fig. 24. Balancing loop of the dynamics of the process of teaching and learning in class.

The eighth mechanism includes attracting external credits. We examined if the University College attracts 1000 million Rial annually as external credits from the government or other organizations, how the behavior of key variables will change? Therefore, we added an external variable to the model.

The ninth mechanism includes allocating internal credits for implementing the programs of education for sustainable development. By allocating 1% income of the University College to the programs of education for sustainable development, we examined this mechanism.

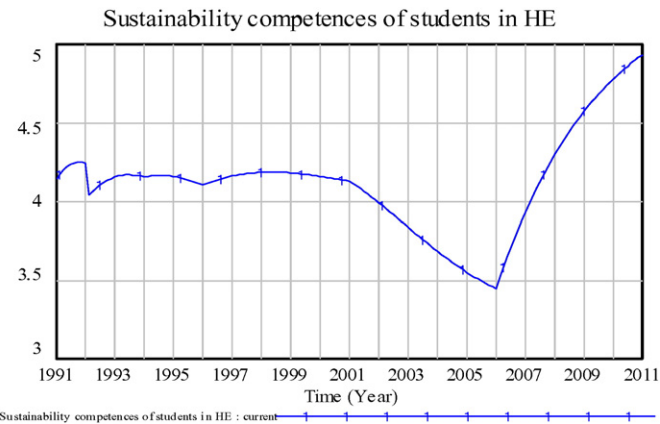


Chart 8. Simulating sustainability competences of students based on the current conditions.

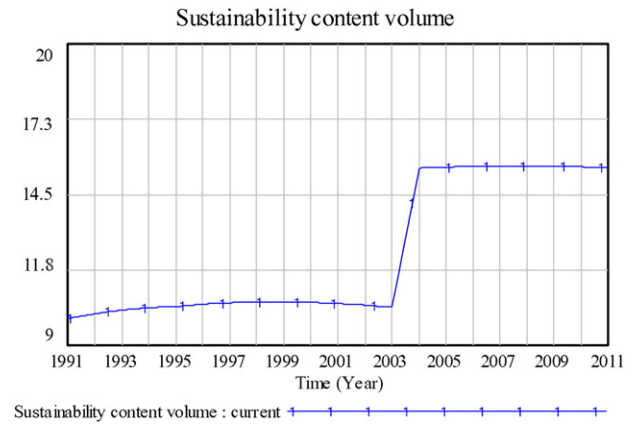


Chart 9. Simulating sustainability content based on the current conditions.

The tenth mechanism includes changing the assessment methods of

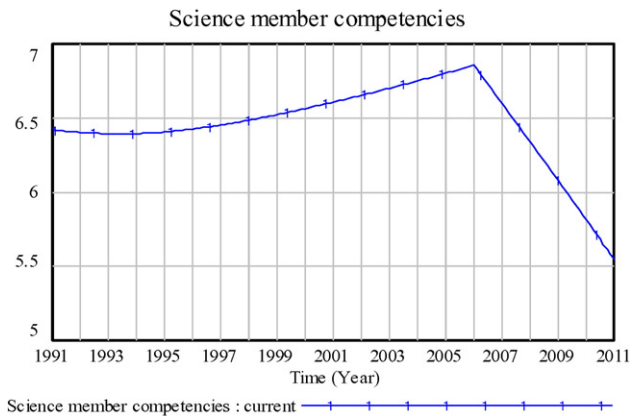


Chart 10. Simulating science members' competencies for education for sustainable development based on the current conditions.

students. Evaluation of this mechanism was done by adding 'assessment index' on the variable of 'mnemonic assessment of student' in the model in the B₆ loop. We assumed that if we move towards the assessment methods of students by 20% change, what will happen to the behavior of key variables?

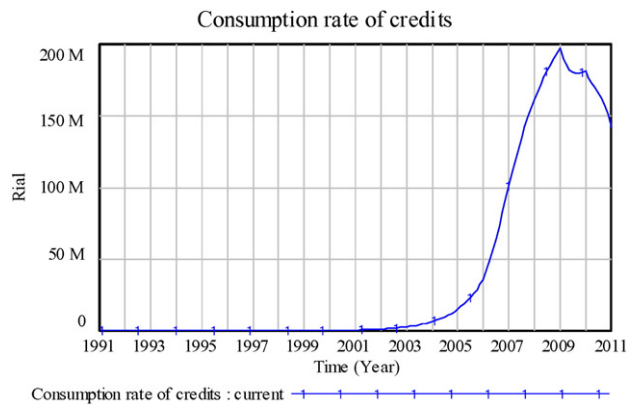


Chart 11. Simulating investment volume for the programs of education for sustainable development based on the current conditions.

Applying appropriate teaching and learning strategies for sustainability education

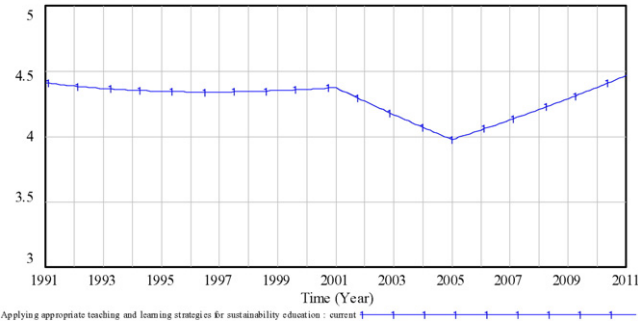


Chart 12. Simulating applying appropriate teaching and learning strategies for education for sustainable development based on the current conditions.

Sustainability competences of students in HE

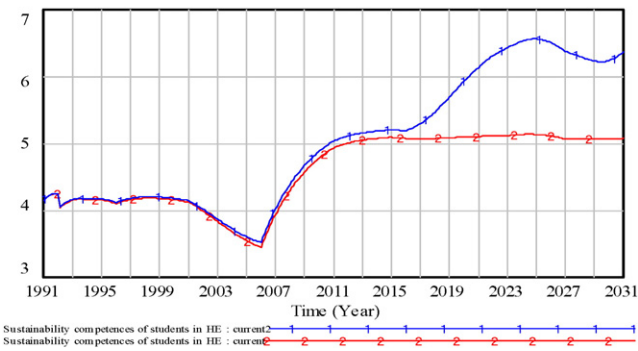


Chart 13. Simulating the behavior pattern of sustainability competencies of students based on the interactions of mechanisms.

The eleventh mechanism includes changing the science members' promotion system through allocating special scores to sustainability researches. This mechanism was evaluated through adding an external variable of 'variations' on 'usual promotion system of science member'. We simulated the behavior of the model by 30% change in indicators of the promotion system in the research section such as allocating more score to the applied researches or patent.

The twelfth mechanism includes changing the promotion system based on the educational processes. In this mechanism like mechanism 11, we assumed that if 30% change in indicators of the promotion system in the educational section occurs, how will be the behavior of model variables?

3.6.2. Evaluating the interactions of the mechanisms

For increasing the impact of mechanisms, we examined the interactions of mechanisms. Based on the conditions of mechanisms such as right time of implementing and being prerequisite mechanisms for each other, we estimated the start time for simulating the mechanisms. For mechanisms 1, 2, 3, 4–1, 5, and 6, the start time was assumed 2014. For mechanisms 4–2, 7, 8, and 9, start time is 2015, and for mechanisms 10, 11, and 12, it is 2016. The results showed that implementation of mechanisms at the right time would have the better effects on the behavior of key variables of dynamic model (Charts 13, 14, 15, 16, and 17).

4. Conclusions

Through analyzing the influencing factors and obstacles to education for sustainable development in higher education, this article created a system dynamic model to develop education for sustainable development in higher education with the emphasis on sustainability competencies of students. The approach of system dynamics helped us to recognize the interventional procedures in fostering competencies of students into the University College.

This model describes the dynamic interactions among the students, science members, content, policy, pedagogy, community, and government.

One of the important factors for the slow and slight development of education for sustainable development in the University College is the lack of the common vision and understanding of the issue of education for sustainable development among the players of this phenomenon such as the science members, managers, and students. This result is in accordance with Van Dam-Mieras (2006), The Higher Education Academy of the UK (2006) and Noonan and Thomas (2004).

All players understand this phenomenon with their knowledge and experiences. These opinions lead to confusion, conflicting decisions, and wasting costs and opportunities in practice. The dynamic model could be used as the base for the common understanding of the phenomenon of education for sustainable development in this case study; as a result, acceptance of our dynamic model is a part of the solution.

The third mechanism that increases the interdisciplinary cooperation, helps to change mental models of science members and students for creating the common mental model. Some studies have pointed out this mechanism to develop education for sustainable development in higher education (e.g., Barth and Michelsen, 2013; De la Harpe and Thomas, 2009; Ferrer-Balas et al., 2008; Hogan and Tormey, 2008; Cohen, 2007; Swansborough et al., 2007; Sterling and Thomas, 2006;

Applying appropriate teaching and learning strategies for sustainability education

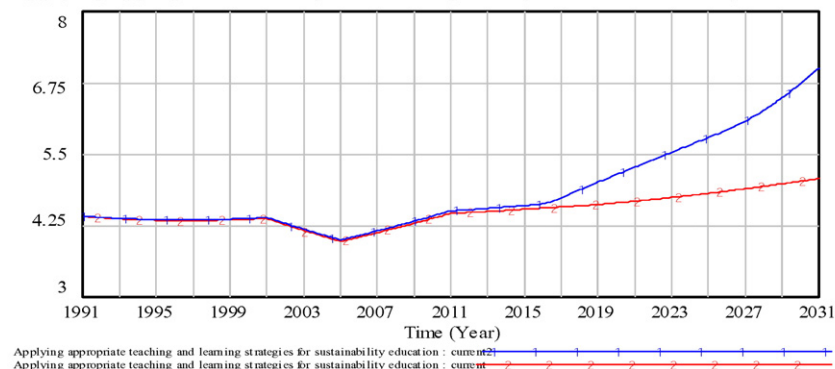


Chart 14. Simulating the behavior pattern of applying appropriate teaching and learning strategies for education for sustainable development based on the interactions of mechanisms.

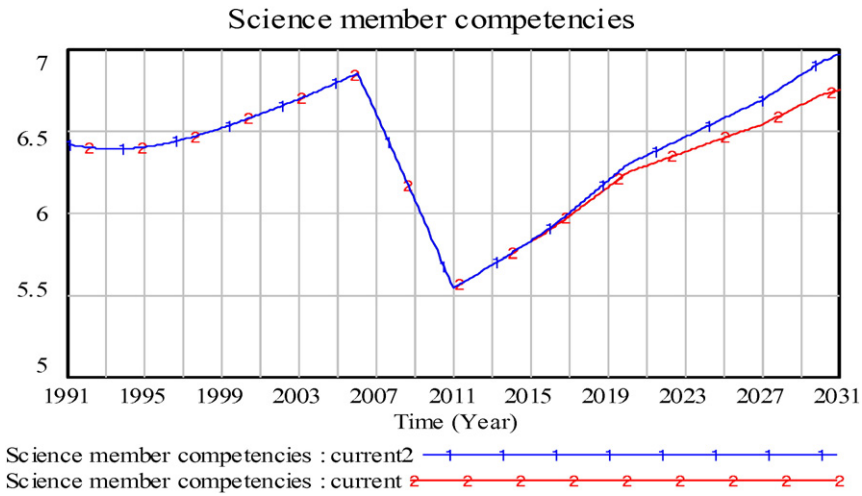


Chart 15. Simulating the behavior pattern of science members' competencies for education for sustainable development based on the interactions of mechanisms.

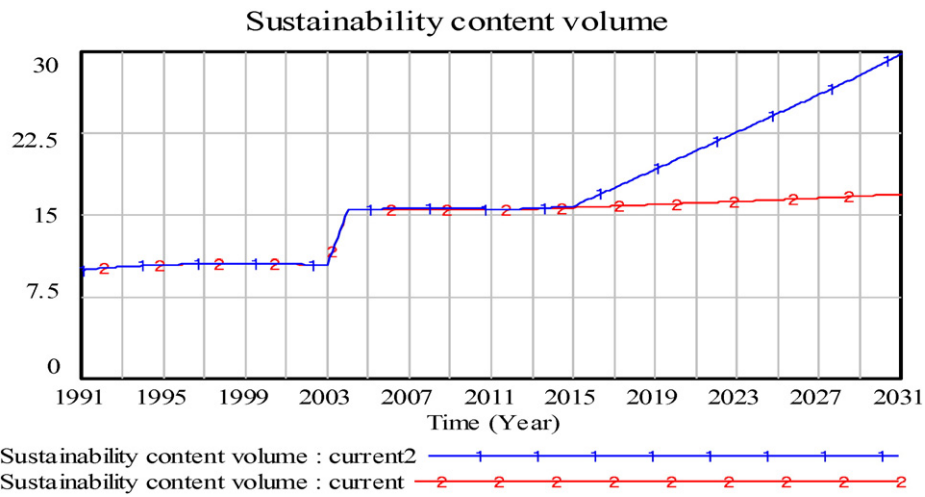


Chart 16. Simulating the behavior pattern of sustainability content based on the interactions of mechanisms.

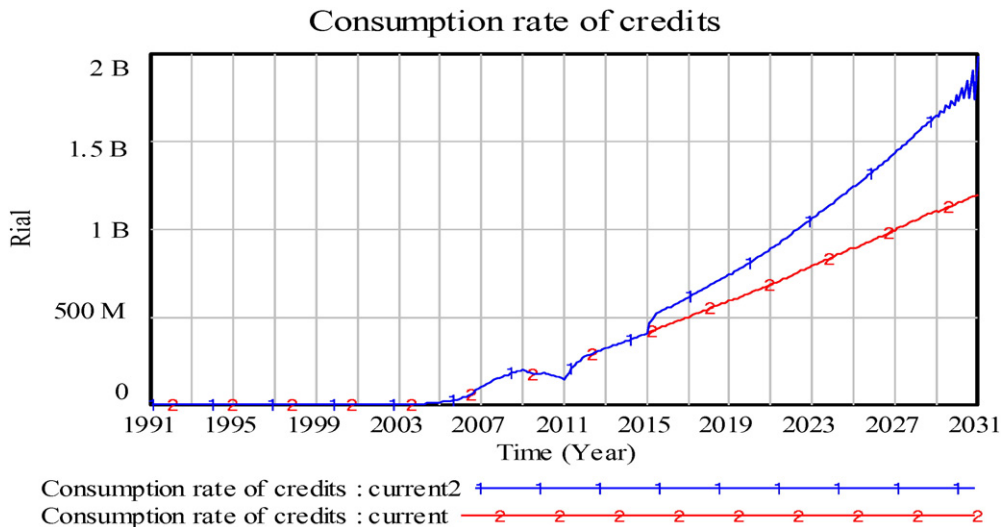


Chart 17. Simulating the behavior pattern of investment volume based on the interactions of mechanisms.

Dawe et al., 2005; Velazquez et al., 2005; Sterling, 2004). Therefore, we can expect to have tendency for the policies of the University College towards education for sustainable development.

Mechanisms 1, 2, 10, 11, and 12, refer to educational changes. Many studies emphasized on capacity building of science members about sustainability knowledge and related pedagogies (Barth and Rieckmann, 2012; De la Harpe and Thomas, 2009; Svanstrom et al., 2008; Cohen, 2007; Litzinger et al., 2007; Fien, 2006; The Higher Education Academy of the UK, 2006; Ali Baigi, 2005; Kolb and Kolb, 2005; Velazquez et al., 2005; Trigwell and Prosser, 2004; Fenner et al., 2004; Ferrer-Balas, 2004; Thomas, 2004; Rowe, 2002). We revealed it in the second mechanisms.

But, they have not considered the promotion or ranking system of science members in the University College as a deeper obstacle to the development of the education for sustainable development. At the moment, the University College is not taking into account the efforts and actions of the science members related to education for sustainable development in their promotion system. Then, they are not motivated to integrate education for sustainable development into teaching and research. Therefore, we presented mechanisms 11 and 12.

The dynamic model of this research and the results of simulating show that we should not expect to solve the problem rapidly. Solutions are presented based on the obvious behavior of players; therefore, these are not adequately responsible for solving this complex problem because of latent layers of the problem. On the other hand, the dynamic model shows resistances and obstacles to the development of the education for sustainable development at the University College. Therefore, it is clear that the majority of resistances belong to the University College.

External resistances in this phenomenon include the deficit of sustainability culture in the community and the budget shortage of organizations in the cooperation with the University College. Therefore, we identified mechanisms in relation to these resistances.

De la Harpe and Thomas (2009), Ferrer-Balas et al. (2008), and Lang et al. (2006) confirm mechanisms 4, 6, and 8. Mechanism 4 was presented because of a hierarchical viewpoint of some science members in the University College. Based on this viewpoint, the reaction of a university to sustainability is often the result of a regular environment that was imposed by the government. Therefore, we should pay attention to the role of the government in promoting sustainability culture in society.

Sustainable society puts pressure on the higher education to train students with more sustainability competencies. Moreover, based on the mechanisms 6 and 8, if the University College could have different income resources: first, it can increase internal credits for investing in the programs of education for sustainable development, and second, it can equip workshops and laboratories to encourage the cooperation from other organizations.

In terms of the seventh mechanism, through revising curricula and removing unrelated content, the University College creates a space for integrating education for sustainable development into the curriculum as well as more time for appropriate teaching strategies for education for sustainable development. In this case, the motivations of science members for education for sustainable development increase. Some studies (e.g., Rieckmann, 2012; Sibble, 2009; James, 2009; The Higher Education Academy of the UK, 2006; Velazquez et al., 2005; Ali Baigi, 2005) confirmed that the university should integrate education for sustainable development into academic content.

Results of simulating showed the findings as follows:

The majority of students don't attempt to qualify and capacity building as a qualified graduate. They always wait for capacity building by the educational system. As Chart 13 shows (current 1), if the University College continues with the same situation, sustainability

competencies of students would not increase in the next 20 years and it would not change. Also, this trend is true for the behavior of integrating sustainability content into the curriculum in the future (Chart 16, current 1).

In Charts 14 and 15 that relate to science members, we see a slight rise in the behaviors of applying teaching and learning strategies for education for sustainable development and science members' competencies in the period from 2015 to 2031 without the interactions of mechanisms (current 1). It is clear that parts of science members' competencies relate to personal development and can increase during the lifetime.

Based on the results, the interactions of mechanisms would have a significant rise in the behavior of all the key variables of the model. Please see current 2 in Charts 13–17.

The model of this research can be simply revised with attention to changes. Also, the mechanisms can be evaluated in the new conditions and different periods of time. It is important to note that the model is capable of generalizing to other universities that have similar players and rules with the case studied in this article.

According to a literature review of this research, we can claim that the model of this research is the first dynamic model to develop education for sustainable development in higher education with the emphasis on the sustainability competencies of students.

4.1. Recommendations for the future researches

When mechanisms are implemented in the real environment, maybe they show some latent aspects which have not been observed in this research. Future researchers can analyze the system after implementing mechanisms in the real conditions. Also, we ignored the effect of the political factors on the system because of high complexity of them. Therefore, it is recommended that other researchers analyze the dynamics of political factors in this system in separate research.

Appendix A. Graduate questionnaire

Gender:

Age:

Academic discipline in Bachelor degree:

Time of graduation in Bachelor degree:

A. Understanding of sustainability and systemic thinking.

At the end of Bachelor period, what did you mean by sustainability?

Instruction: firstly, write concepts and then if there are connections between concepts, show them with arrows. So, please, explain about arrows.

B. Interdisciplinary collaborations

During the Bachelor period, how many interdisciplinary projects did you have in other academic disciplines?

C. Critical thinking in the sustainability

How much capability did you achieve in your Bachelor period through the educational system from the following list?

Item	Issues	Score (0–10)
1	Understanding the interaction of your academic discipline with the social issues	
2	Understanding the interaction of your academic discipline with the economic issues	
3	Understanding the interaction of your academic discipline with the environmental issues	
4	Understanding the interaction of your academic discipline with the political issues	
5	Thinking about your professional role in the community	

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(continued)

Item	Issues	Score (0–10)
6	Analyzing the consequences of your actions and thoughts	
7	Presenting various strategies for your professional problems	
8	Judging on the various solutions a problem based on the economic, social, and environmental issues	
9	Decision-making based on the professional ethics	
10	Evaluating the topics and samples of your academic contents which are connected to sustainable development	
11	Diagnosing the illogical arguments	

D. Creative thinking in the sustainability

How much capability did you achieve in your Bachelor period through the educational system from the following list?

Item	Issues	Score (0–10)
1	Expressing thoughts and votes	
2	Applying your ideas for the professional problems	
3	Ambiguity tolerance in confronting with the ambiguous positions	
4	Responding to questions rapidly and without thinking (negative statement)	
5	To be adjusted with the changes of environment	
6	Producing the ideas and new insights into your professional issues	
7	Interest in the repetitive positions in your profession (negative statement)	
8	Teamwork	
9	Logical argument in the communication with others	

E. Empathy

How much capability did you achieve in your Bachelor period through the educational system from the following list?

Item	Issues	Score (0–10)
1	Identifying oneself with the human	
2	Identifying oneself with the animals and plants	
3	Identifying oneself with the non-human	
4	Identifying oneself with the abstract laws that govern the physical and environmental systems	

F. Commitment to the sustainability

How much commitment did you undertake in your Bachelor period through the educational system from the following list?

Item	Issues	Score (0–10)
1	To respect for earth and life of all	
2	To build the democratic societies that are participatory, sustainable, and peaceful	
3	To secure the earth's bounty and beauty for the present and future generations	
4	To protect and restore the integrity of earth's ecological systems, with special attention to the biological diversity and the natural processes that sustain life	
5	To prevent the harm as the best method of the environmental protection (apply a precautionary approach)	
6	To adopt the patterns of production, consumption, and reproduction that safeguard earth's regenerative capacities, human rights, and community well-being	
7	To try to do the studies about ecological sustainability	
8	To eradicate poverty as an ethical, social, and environmental issue	
9	To consider the gender equality as prerequisites for the sustainable development and promote women's participation in professional projects	
10	To uphold the right of all without the discrimination	
11	The attention to the rights of the indigenous peoples	
12	To apply the participatory problem-solving in the environmental management	
13	To encourage and support the mutual understanding, solidarity, and cooperation among all peoples	

G. Respect for the past, present and future generations

How much belief did you get in your Bachelor period through the educational system from the following list?

Item	Issues	Score (0–10)
1	To conserve the diversity of natural and cultural resources	
2	To conserve the resources that are unusable for the present generation	
3	To maintain the quality of the planet by the present generation	
4	To conserve the past and present heritage	
5	To conserve ecological endowments such as a natural landscape due to their importance in human welfare	
6	The attention to the destructive impacts of your projects for future generations in economic, social, and environmental contexts	

H. Applying appropriate teaching and learning strategies for education for sustainable development

How good was the level of your educators in applying related strategies in teaching processes in your Bachelor period?

Item	Issues	Score (0–10)
1	Expressing the applications of the disciplinary content in the real situations	
2	Connecting to the different issues in the class	
3	Providing the learning opportunities using field visits	
4	Providing the practical exercises and projects for the students	
5	Expressing the issues related to the teaching content in the format of the question	
6	Use of the different samples for applying theoretical concepts	
7	Use of the different educational tools in the class	
8	Providing the opportunities for the students to participate together (a group working)	
9	Providing the opportunities for the students to present solutions related to problems	
10	Providing the opportunities for the students to connect with the nature	
11	Use of the educators of the personal experiences as examples of issues presented in the teaching	
12	Providing the opportunities for the students for the use of campus as a laboratory for their actions and better understanding	
13	Providing the opportunities for students to use the environment as the place for the professional services and practical work	
14	Respect the educators for the viewpoints of the students and the use of their ideas in teaching	
15	Providing the opportunities for the students to express their opinions concerning content	
16	Providing the opportunities for the students to discuss real-world issues (globally or locally) and connect them with discipline	
17	Providing the opportunities for the students to image the content in the mind	
18	Providing the opportunity for the students to reflect on the content in the class	
19	Providing the opportunities for the students to express their disagreement	
20	Providing the opportunities for the students to think about cultural, social, economic, and environmental consequences of the actions and decisions related to the discipline in the local, national, and global levels	
21	Encouraging students to use the real world issues for doing class assignments	
22	Providing the opportunities for the students to express the feelings concerning subjects	
23	Analysis and assessment of actions in different places (locally and globally) as part of content by educators	
24	Use of the simulation methods for presenting the professional issues	
25	Use of the teaching team in a course	
26	Formation of the learning groups in the class	
27	Giving the multidisciplinary exercises and projects	

Appendix B. Science member questionnaire

Gender:
 Age:
 Department:
 Time of recruitment in university:
 Please, identify the level of the abilities in each of the competencies.

Item	Issues	Score (0–10)
<i>Competencies related to sustainability knowledge</i>		
1	Ability to select the educational goals of the sustainability	
2	Sustainability knowledge	
3	Ability for networking in order to acquire the knowledge of relevant sustainability issues	
4	Ability to contribute sustainability content into university curriculum	
5	Ability to cooperate with organizations which promote sustainable development	
<i>Competencies related to values and ethics</i>		
1	Ability to encourage the students to explore their beliefs and assumptions	
2	To be aware of societal tensions related to sustainable development and education	
3	Ability to analyze the underlying structure and the reasoning which supports sustainable development to participate in the decision-making processes for the society	
4	Ability in not imposing your own values and opinions to the students	
5	Ability to integrate values which underpin sustainable development into personal and institutional life	
6	Ability to help students in acquiring plural perspectives on issues	
7	Ability to focus on students' discussions on their values	
8	Ability to offer the opportunities to the students in order to confront diversities and look at them as opportunities	
9	Ability to offer the opportunities to the students to distinguish between factual knowledge and value-based opinions and investigate the beliefs and interests behind them	
10	Ability to apply the conflicting beliefs and values of students in teaching processes	
11	Knowledge about a range of teaching methods related to values, i.e.: a research based learning, real life learning, project learning, role play games, discussion forums	
12	Ability to focus on the understanding of citizenship, including the rights and responsibilities	
13	Ability to participate in structural or institutional change within society	
14	Ability to build common understandings, identify common challenges and strengthen common commitment in order to plan joint actions	
<i>Competencies related to system thinking</i>		
1	Ability to understand the basic models of systems theory	
2	Ability to apply the system thinking in different situations and for different issues	
3	Ability to encourage the students to look at issues from different perspectives	
4	Ability to guide the students in the development of empathy by identifying themselves with others	
5	Ability to foster the student's insight through learning issues	
6	Ability to help the students to select among different issues	
7	Ability to encourage the students to reflect on themselves and their environment, and short- and long-term consequences of their actions	
8	Ability to enable students to face ambiguity, uncertainty, and complexity	
9	Ability to encourage the students to reflect on their environment to look for different solutions	
10	Ability to encourage the students to implement their plans	
11	Ability to help the students to create a sense of the connection to place, others and the world	
12	Ability to perceive the university as a living system	
13	Ability to establish the cooperation among university, industry, and society	
14	Ability to know ways to establish the partnerships with other educational institutions in order to generate and exchange the	

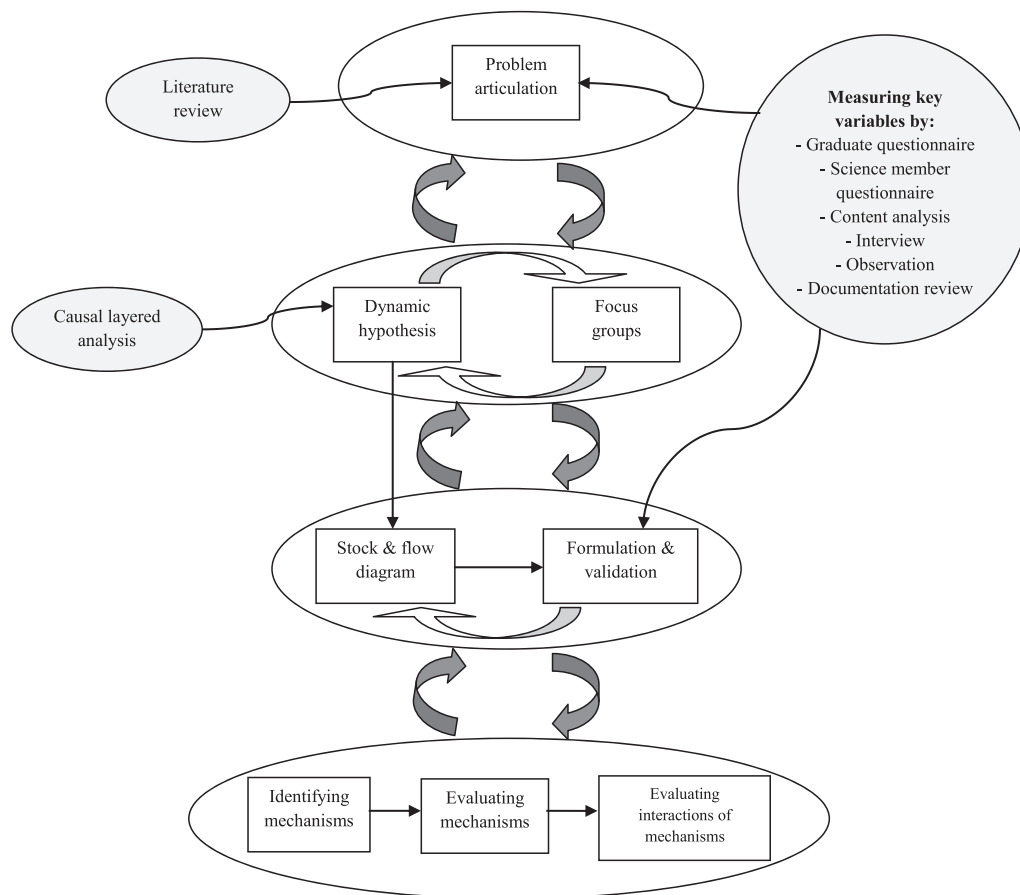
(continued)

Item	Issues	Score (0–10)
15	ideas Ability to identify and analyze the power relationships and understand the causes	
<i>Competencies related to emotions</i>		
1	Ability to express and manage emotions and feelings	
2	Ability to be aware of the impact of emotions on perception, judgment, decisions and actions in your life and the life of students	
3	Ability to the development of the competencies of compassion and empathy in yourselves	
4	Ability to be aware of the difference between dealing with the emotions within your class or university and the surrounding society	
5	Ability to create an atmosphere that allows students to express his feelings and ideas without fear of failure	
6	Ability to create learning situations and an appropriate atmosphere so that students are able to develop feelings of empathy with other human and nature	
7	Ability to know how to stimulate responsibility in students	
8	Ability to help students to develop emotional competence to consciously make choices and to plan actions	
9	Ability to work with real issues connected to the life of the students	
<i>Competencies related to action</i>		
1	Ability to imagine the alternative futures and new and creative solutions	
2	Ability to act as a change agent for achieving the sustainability goals	
3	Ability to reflect on the lifestyle and choices	
4	Ability to solve the problem	
5	Ability to deal with the uncertainty	
6	Ability to share the responsibility in the teaching process with the students	
7	Ability to consider action as an educational value, not only as a way to solve the problems	
8	Ability to find the opportunities for learning processes in the real-world, especially topics which are in accordance with sustainability	
9	Ability to organize and facilitate the visioning among students as the basis for action towards sustainability (imagine a better future)	
10	Ability to analyze and describe the local society through sustainability dimensions	
11	Ability to deal with the political situations, thinking and strategic action	

Appendix C. Main, generic, and subcategories for the content analysis

Main category	Generic categories	Subcategories
Sustainability	Environmental	Biodiversity; climate change; environmental management; exploitation of the non-renewable resources; reuse; environmental pollutions; conservation, development, and rehabilitation of the natural resources; erosion reduction; prevention of the natural disasters; assessment of the projects based on the environmental indicators
	Social	Human and environment; intergenerational justice; social responsibility; system thinking; gender equality; peace and human security; quality of life; professional ethics; assessment of the projects based on the social indicators
	Economic	Sustainable business; sustainable production and consume; sustainable livelihood; food security; financial saving; poverty alleviation; assessment of the projects based on the economic indicators
	Institutional	Participation stakeholders and different players; international and national rules and policies; decision-making; planning (short term, medium term, long term); participatory management

Appendix D. Diagram of research processes



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